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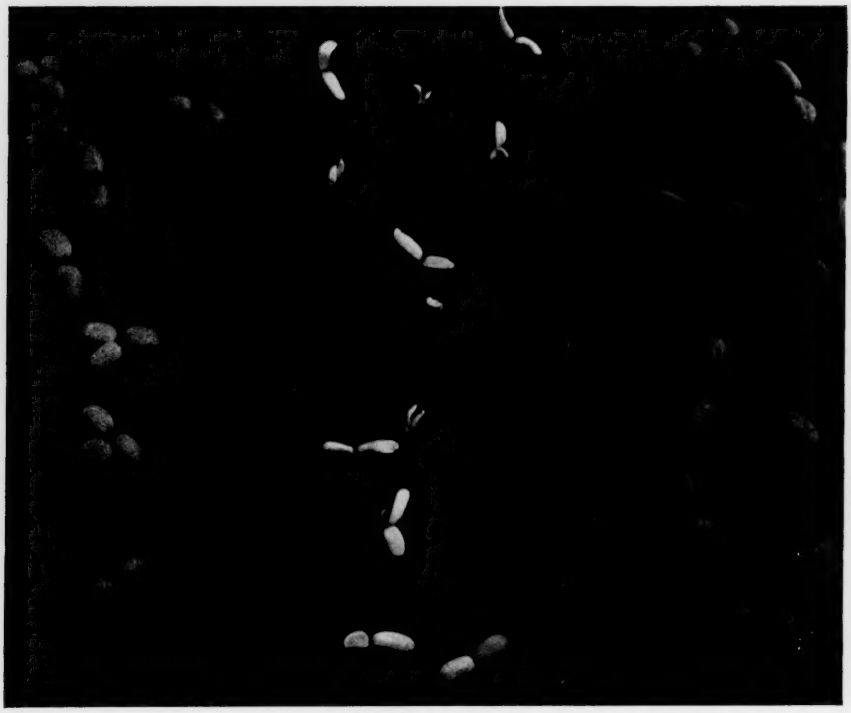

CHLOROPHYLL-DEFICIENT HYBRIDS BETWEEN TWO SWEETCLOVER SPECIES

(SEE PAGE 135)

Twin Barley Seedlings

The Old-Type Navajo Sheep

Genetics of Dwarf Rice Mutations

Resistance of Polyploids to X-ray Effects

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The American Genetic Association

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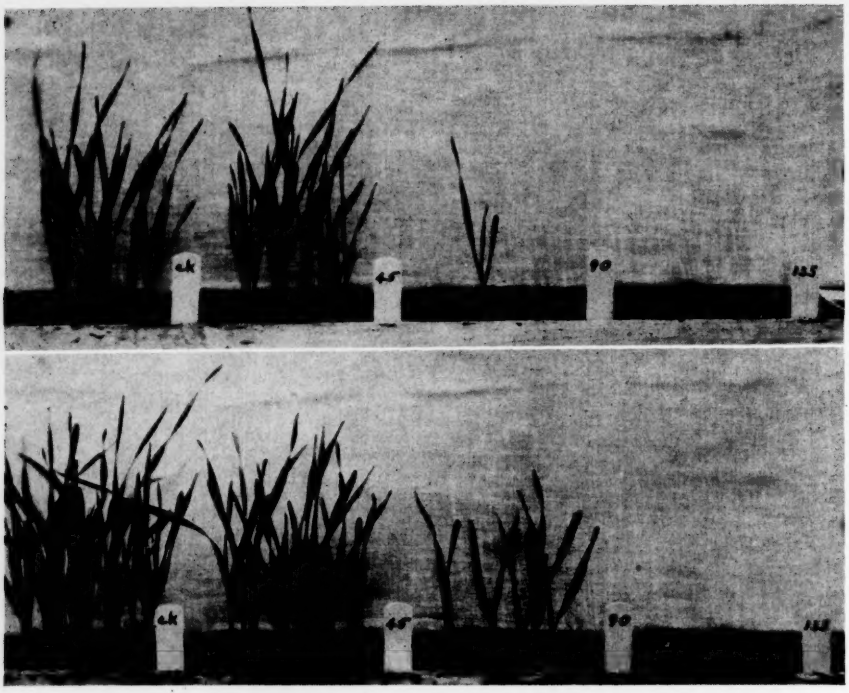

RYE SEEDLINGS FROM HEAT-TREATED SEEDS

Figure 1

Rye seedlings following heat treatments of dormant seeds. Top: Autotetraploid, left to right—Control, 45 min., 90 min., 135 min. at 80° C. Bottom: Diploid, corresponding treatments. Seedlings 17 days old. Observe that the autotetraploid shows as much (or greater) susceptibility to heat injury as the diploid.

MAIZE SEEDLINGS FROM IRRADIATED SEEDS

Figure 2

Maize seedlings following X-ray treatments of dormant seeds. Front row: Diploid, 16,000 r, 27,000 r, 38,000 r. Back row: Autotetraploid, corresponding treatments. Seedlings 30 days old. Note the distinctly greater injury to the diploid.

RELATION OF POLYPLOIDY TO HEAT AND X-RAY EFFECTS IN THE CEREALS*

LUTHER SMITH†

THIS is a preliminary report of experiments conducted on certain of the cereals to determine the effects of heat and X-rays on dormant seeds and of X-rays on mature pollen, with particular reference to the relation of these effects to chromosome number. Detailed data and a more complete discussion of the problem are to be published later.

The experiments reported here deal with: (1) The tolerance for heat and X-rays of dormant seeds of diploid (n=7), tetraploid (n=14), and hexaploid (n=21) species of wheat and oats; diploid and autotetraploid strains of barley (n=7), rye (n=7), and maize (n=10); and an amphidiploid hybrid between diploid (n=7) species of wheat and species of *Aegilops*. (2) The effect of combinations of heat and X-rays on dormant seeds of diploid wheat and barley. (3) The effects of heat and X-ray treatments of dormant seeds on the frequency of mutations in diploid wheat. (4) The effects of heat and X-ray treatments of dormant seeds on the frequency of translocations in diploid and tetraploid wheat. (5) The effects of irradiation of mature pollen of diploid, tetraploid, and hexaploid wheat on cytological irregularities.

Materials and Methods

Conditions of treatment, germination, and growth, in so far as possible, were identical in the comparisons between stocks. Seeds were given heat treatments in corked vials and germinated either on blotters or in soil in the greenhouse. Most of the seedlings were discarded after about one month. Some were transplanted and grown to maturity in the field, though most of the plants examined cytologically were grown in the greenhouse.

The heat treatments applied included temperatures of 50°C, 55°C, 60°C, 65°C, or 70°C for 5, 10, or 15 days and 80°C for 45, 90, 135, or 180 minutes. Not all treatments were applied to each stock.

The X-ray apparatus was operated at about 130 KVP., 4 ma. tube current.

Cytological observations were made on aceto-carmine smear preparations.

Experimental Results

Heat Tolerance of Dormant Seeds

The tolerance of dormant seeds for heat did not increase with chromosome number. Seeds of tetraploid and hexaploid species of wheat and oats, and of autotetraploid strains of barley, rye (Figure 1), and maize, and an amphidiploid hybrid of wheat and *Aegilops* did not survive heavier treatments than did the diploids.

X-ray Tolerance of Dormant Seeds

The results with X-rays were distinctly different from those with heat. In agreement with the observations of Stadler[8] and various others, it was found that tolerance for X-rays increased with the degree of polyploidy. The autotetraploid stocks of barley, rye, and maize survived the treatments with less evidence of injury than the corresponding diploids (Figure 2), and in the species of wheat and oats, the hexaploids tolerated heavier doses than did the tetraploids.

Tolerance for Combinations of Heat and X-rays

These experiments were conducted to determine whether heat and X-ray treatments would result in additive injurious

*Cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Field Crops Department, Missouri Agricultural Experiment Station. Journal Series Paper No. 862.

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effects when various combinations of treatments were applied to dormant seeds. Comparable lots of dormant seeds of diploid wheat and barley were given heat or X-ray treatments alone, and combinations with heat either preceding or following the X-ray treatment. For each trial the X-ray apparatus was operated only once, so the irradiation was largely a constant factor. All series were planted in soil immediately after the treatments were completed. In most cases the combined heat and irradiation treatments were completed in three or four hours.

One series of treatments on the diploid wheat included:

Control (10 seeds)
6,000 *r* (10 seeds)
45 min. at 80° C (10 seeds)
6,000 *r* plus 45 min. at 80°C (10 seeds)
45 min. at 80°C plus 6,000 *r* (10 seeds)

These treatments and other similar series on larger numbers of seeds showed that the order in which the combined treatments were applied had a distinct effect on the amount of injury caused. When X-ray treatment was followed by heat treatment the resulting seedlings were injured more than those from seeds given X-ray treatment only. On the other hand when the heat treatment preceded the irradiation the seedlings showed less injury than those from seeds given X-ray treatment only. Seedlings from seeds that had been in a dessicator for two or three days before irradiation were damaged about as little as those in which the heat treatment had preceded irradiation.

Although the experiments were inadequate to permit a complete explanation of these results, it appeared that moisture content of the seeds may have been an important factor affecting injury in the combined heat and X-ray treatments. Barley seeds placed in the dessicator for two days lost 0.7% of their initial weight, and those left for three days lost 1.0%. The wheat seeds treated for one hour at 80°C lost 0.9%. Thus it may be that a decrease in moisture resulting from pretreating with heat or drying over calcium chloride caused the decrease in injury from irradiation. However, the moisture content probably cannot be used to explain the cumulative injury from heat following irradiation. This observation indicates that heat and X-rays do have certain effects which are additive in spite of the contrasts between these agents already known and shown in the experiments of this report.

Mutation Frequency After Heat and X-ray Treatments of Dormant Seeds

Mutation rates following heat and X-ray treatments of seeds of diploid wheat are shown below:

Treatment	Head progenies No.	Mutants No.	Heads with mutants %
Control	407	5	1.2
Heat	1015	6	0.6
X-ray	3363	121	3.6

Most of the irradiated seeds were given 5,000 *r*; the rest were given 7,500 *r*. The heat treatments included temperatures of 60°C for five and ten days, 65°C for 15 days, and 70°C for five days. Apparently the X-rays were effective and the heat treatments ineffective in increasing the frequency of mutations.

Cytological Effects of Heat and X-rays

Bridges in Somatic Cells in Relation to Polyploidy

Root tips from seeds treated with heat or X-rays while dormant were examined cytologically for the frequency of bridges in late anaphase and early telophase stages. Seeds of diploid, tetraploid, and hexaploid wheat were treated for this comparison. After the treatments, given as in previous experiments, the seeds were immediately started to germinate on blotters. The root tips were fixed one to four days after treatment. Aceto-carmine smears were made of these tips and the frequencies of bridges determined.

It was clear that the heat treatment (80°c for one hour) did not increase the number of bridges in any of the stocks. On the other hand the X-ray treatment of 10,000 *r* produced a marked increase in the frequency of bridges, and there was a definite increase in the frequency of bridges with each increase in chromosome number. In the diploid

there were .7; in the tetraploid 1.7; and in the hexaploid 2.2 bridges per cell. A similar result for the effects of X-rays was reported by Frőier, Gelin, and Gustafsson.[1]

Translocations in Relation to Polyploidy

The occurrence of reciprocal translocations following treatments of dormant seeds of diploid and tetraploid wheat was determined by cytological examinations of pollen mother cells of plants grown from treated seeds.

The results were similar to those obtained from observations on the frequencies of bridges in somatic cells. The heat treatments had little, if any, effect on the production of translocations, whereas X-rays (5,000 *r*) produced a marked increase and the increase was more pronounced in the tetraploid. In the diploid there were .22 and in the tetraploid .41 rings of four per spike examined.

Irradiation of Pollen

The purpose of this experiment was to determine the relation between the number of chromosomes and the frequency of reciprocal translocations produced by a given dose of X-rays. For this study mature pollen of diploid, tetraploid, and hexaploid wheat was irradiated (520 *r*) and applied to stigmas of untreated spikes. Pollen mother cells of the resulting plants were examined for the presence of translocations. The results are presented in Table I. The occurrence of fragments and whole chromosome deficiencies (not shown in the table), particularly in the hexaploid but also in the tetraploid, as contrasted with their almost complete absence in the diploid, makes accurate interpretation difficult. Most fragments represent visible deficiencies, and other, lesser deficiences must also have been present. The differential survival of gametes and zygotes with deficiencies was strongly associated with the degree of polyploidy and hence diminishes the value of a comparison of the number of translocations. However, the data show that as the number of chromosomes increased there was a big increase in the number of recovered translocations. The increase is presumably due in large part to the fact that as the number of chromosomes increased the number of breaks due to irradiation increased with the result that new alignments of chromosomes (i.e. translocations) could occur with greater frequency.

Discussion

These experiments show a number of contrasts between the effects of heat and X-rays on dormant seeds. The differences may be of value in the interpretation of the processes which have been important in producing heritable variations on which natural and artificial selection have operated. High temperatures, even for several days, were relatively, if not completely, ineffective in causing genetic changes in dormant seeds. This does not mean that other temperatures or other conditions would be equally ineffective. However, it is clear that there is a difference in the type of response of dormant seeds to heat and X-ray treatment, although in some trials, treatments of X-rays followed by heat were cumulative in their injurious effects. Peto[3,4] reported that

TABLE I. Translocations from X-rayed pollen of wheat (520 r).

Species	Plants with translocation configurations R_4	$2R_4$	$3R_4$	R_6	R_4/R_6	$2R_4/R_6$	R_8	Total plants examined	Rings of 4 per plant*
	No.	No.	No.	No.	No.	No.	No.	No.	No.
Triticum monococcum (Diploid 2n=14)	46	2		4				192	0.3
T. durum (Tetraploid 2n=28)	77	22	1	10	8		4	214	0.8
T. vulgare (Hexaploid 2n=42)	67	60	17	14	14	11	5	235	1.6

* This figure was calculated by converting the more complex configurations (some of which---such as rings of ten, etc.,---are not shown in the table) into their equivalents in rings of four.

heat treatments were effective in producing chromosomal irregularities in dormant and germinating seeds of barley. The "chromosomal mutants" produced in the dormant seeds "consisted almost entirely of fragments." For other results and references to genetic effects of heat see Randolph[5] and Sax,[7] and for results on the effect of temperature during (as well as before and after) irradiation on X-ray sensitivity of maize seeds see Kempton and Maxwell[2] and Maxwell, Kempton, and Mosley.[3]

Summary

The heat tolerance of dormant seeds of several species and strains of five genera of cereals was independent of chromosome number. The observation of other investigators that tolerance for X-rays is correlated with polyploidy was verified on the polyploid series in wheat and oats, and extended to autotetraploid strains of barley, rye, and maize, and an amphidiploid of wheat and *Aegilops*. In tests combining heat and X-rays in successive treatments, it was found that treating with heat prior to irradiation decreased the sensitivity of seeds to irradiation, whereas if the order of the treatments was reversed the heat treatment increased the injury to the seeds. The decrease in injury obtained by pretreating with heat was associated with a decrease in the percentage of moisture in the seeds.

Heat treatments of dormant seeds of diploid wheat had little, if any, effect on mutation rate. X-rays definitely increased the frequency of mutations.

Heat treatments of dormant seeds had little, if any, effect on the number of chromatic bridges in root tip cells. On the other hand, X-rays greatly increased the number of bridges, and the increase was associated with the degree of polyploidy.

Heat treatments of dormant seeds had little, if any, effect on the number of translocations. X-rays had a marked effect and the frequency was greater in tetraploid than in diploid wheat.

The frequency of translocations in irradiated pollen of diploid, tetraploid, and hexaploid wheat increased greatly with each increase in chromosome number.

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✦

The Facts of the Case

What, then does science mean to me? The answer includes elements of admiration, disillusionment and faith.

In essence, science represents an unbelievably large collection of facts and interpretations of these facts, relating to every known area of the natural world. Acquisition of this information and application of it in the arts and industry are the glory of the scientific method.

Science and the scientific method are primarily human tools. They provide information and means for action; but they do not suffice in themselves to make any one act or, in case of action, to direct it to human good. The latter ends, if we want them, necessitate transformation and direction of our motivation by other means.

The scientific approach is the most effective procedure thus far discovered for enabling us to understand, and to adjust ourselves to, the physical world. In doing this we may well turn to Glenn Frank for our motto. "Let's stop being radicals or conservatives," he said, "and be scientists. That is, let's *act* in the light of the facts in the case, rather than in the (twi)light of our prejudices or the faded labels of our class, our clique, or our clan."—M. G. Mellon, "Science, Scientists and Society," *Science*, 97:368.

PROPAGATION OF CHLOROPHYLL-DEFICIENT SWEETCLOVER HYBRIDS AS GRAFTS*

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THE high content of coumarin in the two species of sweetclover, *Melilotus alba* and *M. officinalis*, now being grown as forage plants, makes the forage relatively unpalatable to livestock and under certain conditions its presence allows the formation of a poisonous substance[4,5] in hay and silage. This poisonous substance may occur in amounts sufficient to cause severe and often fatal hemorrhage in animals feeding on the spoiled hay or silage. Stevenson and White[6] have developed a strain of *M. alba* much lower in coumarin content than the average of the species. They found, however, that the coumarin-deficient strain may form significant amounts of coumarin under certain conditions. A still lower coumarin content, therefore, may be necessary to avoid the hazard of poisoning. Another species of clover, *M. dentata*, meets this requirement. It belongs to *Eumelilotus*, the same section of the genus in which *M. alba* and *M. officinalis* occur, but lacks the aggressiveness and productivity of these common forms. Brink and Roberts[1] found that the vegetative tissues of *M. dentata* are free of coumarin and that only a small amount occurs in the seed. Furthermore, on subjecting the forage of this species to conditions favorable for the development of the poisonous substance, Smith and Brink[4] found that the hay did not induce the disease symptoms in the rabbit.

Numerous attempts have been made to cross *M. dentata* with the common sweetclovers, but the F_1 hybrids are chlorophyll-deficient. Stevenson and White[6] crossed *M. dentata* with *M. alba*, *M. officinalis* and *M. suaveolens*, but none of the hybrids survived longer than two or three weeks after emergence. During the past year chlorophyll-deficient F_1 hybrids of *M. alba* × *M. dentata* have been raised to maturity by grafting them on the common sweetclovers.

Materials

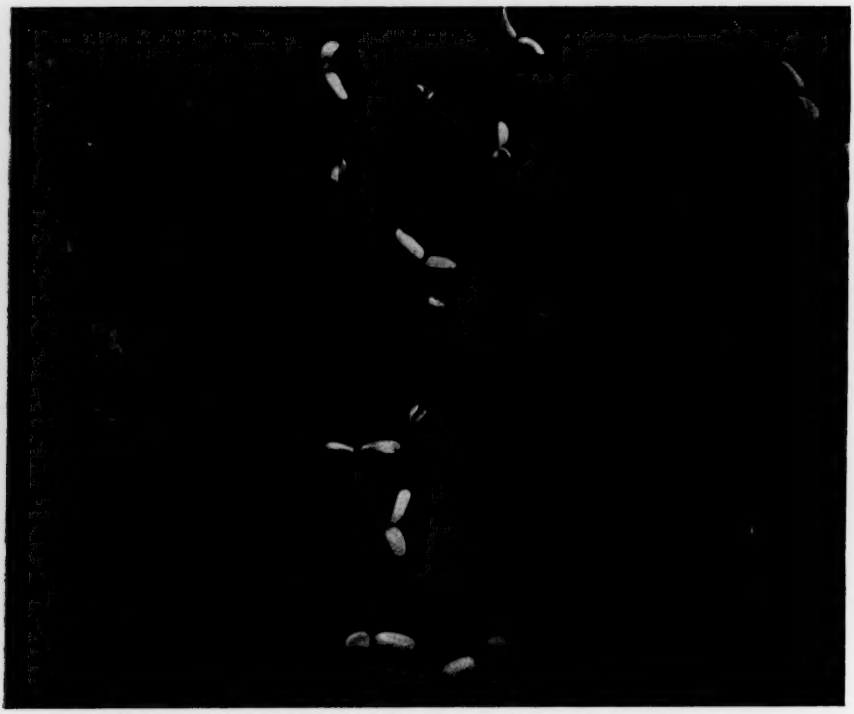
M. dentata appears to be predominantly biennial but, as in some of the other species of *Melilotus*, annual forms occur. In the present studies three strains of *M. dentata*, one biennial and two annual have been used: The biennial form designated as Ac91 was obtained from Saratov, U.S.S.R., through the Bureau of Plant Introduction, Leningrad. One annual form was collected in Czechoslovakia by Dr. Anton Frőhlich; the other annual strain was introduced by Dorsett and Morse from Peiping, China, in 1928. This latter strain was the staminate parent of the hybrids raised to maturity.

A number of strains of *M. alba* including the annual form Hubam have been used in the crosses. The pistillate parent of the hybrids described in this paper was derived from a sample of seed obtained in 1933 from the Botanic Garden in Madrid, Spain.

Methods and Experimental Results

Under greenhouse conditions, practically all strains of *M. dentata* set pods without insect visitation or manipulation of the flowers. Tripping of the flowers is necessary for the development of fruits in *M. alba*. Consequently, in crossing the two species, it was convenient to use *M. alba* as the pistillate parent. Seeds thus produced vary widely in degree of

*Cooperative experiments between the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture and the Departments of Genetics (Paper No. 301) and Agronomy, Wisconsin Agricultural Experiment Station.



SEEDLINGS OF *M. ALBA* × *M. DENTATA* F_1 AND OF PARENT SPECIES
Figure 3

Left, *M. dentata;* center, *M. alba* × *M. dentata* F_1; right, *M. alba.* The F_1 seedlings are chlorophyll-deficient, slower in development, and normally survive for only 10-15 days. Three *M. dentata* seedlings have three cotyledons; the character has been noted in *M. dentata* only in this one self-fertilized line.

development. Some are small, shrivelled, dark brown in color, weigh only 0.5 mg. or less and do not germinate whereas others are plump, of good color and weigh two mg. or more. Differences in the proportions of well-developed and abortive hybrid seeds formed were apparent among plants.

The hybrid seedlings are readily distinguished from those arising from accidental self-pollination by the pale green color of the cotyledons (Figure 3). The hybrids develop more slowly than normal seedlings due apparently to the lack of chlorophyll. In color the seedlings range from practically colorless to very pale yellowish green. Differences in vigor are correlated with the color: the smaller and weaker seedlings tending to be paler. All eventually died. The more robust plants survived for three weeks under favorable conditions for growth in the greenhouse; or, in a few instances, until the unifoliolate leaf had attained a length of two or three millimeters. Attempts to stimulate development of chlorophyll by spraying with dilute solutions of copper and iron salts were ineffective.

The possibility of promoting the growth of the hybrids by graft union with normal plants was then investigated. An attempt was made to establish union between the hypocotyls of a chlorophyll-deficient and a normal green seedling while both were rooted in the

GRAFTED CHLOROPHYLL-DEFICIENT HYBRID

Figure 4

The tall stem bearing flowers is the grafted *M. alba* × *M. dentata* F_1. The host plant, in this instance a plant of *M. alba*, was clipped at intervals.

SEED PODS

Figure 5

Seven pods developed on one *M. alba* × *M. dentata* F_1 plant when *M. alba* pollen was applied to the stigmas. Five of the pods occurred as a group on one raceme.

soil and growing side by side. A thin tangential slice was cut from the hypocotyl of each seedling on the adjacent sides, and the cut surfaces were bound together by tying with a soft thread. No beneficial effect of this treatment was observed in four hybrids tested.

In another trial an attempt was made to induce union between a chlorophyll-deficient seedling rooted in the soil and the shoot of a sweetclover plant in the early stage of its second year of growth. One seedling of four thus treated survived for over five weeks but growth was slow and did not proceed beyond the expansion of the unifoliolate leaf.

Satisfactory development of the hybrids was later obtained when the seedling was severed from the root at the base of the hypocotyl and inserted as a cleft graft on a vigorous shoot of a common sweetclover plant. Field-grown plants to be used as stocks were potted

toward the end of the first year of growth. They were held in a slowly-growing condition at a low temperature until a few days before use and were then brought into a warm greenhouse. When the strongest shoots were approximately six inches long, the distal one-quarter of a shoot was removed just above a node and discarded. The tip of the portion of stem left on the plant was split for about half an inch and the pith of one half gouged out. The seedling to be grafted was then dug, the root was cut off at the base of the hypocotyl and a thin slice removed from two sides of the hypocotyl leaving it blunt and wedge-shaped. This scion was then inserted in the cleft and the cut ends of the stem were held together with a soft thread.

All grafts were shaded from the direct rays of the sun until the scions were established. In some instances the host plant was covered with a bell jar for 24 hours but this protection was not essential. The other shoots of the host plant were trimmed back from time to time as development proceeded in order to favor the growth of the graft (Figure 4). Three hybrids thus grafted on common sweetclover produced flowers. One of the hybrids had been grafted on a plant of *M. alba* and the other two were reared on *M. officinalis*. Only one of the three hybrids bore seeds and it was one of the two grafted on *M. officinalis*.

Mention has been made that the color of the hybrid seedlings is a pale yellowish green. After grafting, the green color tends to deepen. Prior to the appearance of flower buds, the color of the foliage was a yellowish green corresponding to Ridgway's "Javal Green"[2] while that of the parent strains was "Leaf Green."

Comparison of Hybrids with Parents

Observations of characters in which the two parent strains are sharply contrasted were made on hybrids and parents. The two parental species differ in habit of growth: the *M. alba* parent strain is a biennial and the *M. dentata* strain an annual. There is no good evidence concerning the inheritance of this character in the *M. alba* × *M. dentata* cross. The distinction between the annual and biennial habit as expressed in the field is not as clear-cut for the conditions under which the material was grown in the greenhouse. Moreover, studies with other genera have shown that, for a given photoperiod, the character of the stock may affect the onset of flowering in the scion.

It may be noted, however, that in each of the two species *M. alba* and *M. dentata,* the annual habit is dominant to the biennial.

Stipule. The size of the stipule may vary with the vigor of the plant but the shape is sharply contrasted in the two species. In the *M. alba* parental strain, the stipule is bristle-like and entire except that at the lower nodes it may be incised; in the *M. dentata* strain, it is awl-shaped and deeply dentate. The stipules in the hybrids closely resembled those of *M. alba.*

Flower Color. The flower of *M. alba* is usually referred to as white but a trace of color is present. The color is most pronounced at the base of the standard and runs along the midvein. It corresponds to Ridgway's "Pale Dull Green Yellow." In the *M. dentata* parent, the color of the flower is a "Lemon Chrome" in the distal half of the standard but blends into "Lemon Yellow" in the proximal half as well as in the wings and keel. In the F_1 hybrid, the color tends to be intermediate between that of the two parents. It is not evenly distributed over the petals but is most conspicuous along the midvein of the standard and the distal third of the wings. The color is "Pale Greenish Yellow."

Ovule Number. The number of ovules in the ovary of typical forms of the species *M. alba* is four but botanical varieties are recognized by Schulz[3] as having two or three ovules per ovary. The strain of *M. alba* used as the pistillate parent in this cross has fewer ovules

TABLE I. Number of Ovules in Ovaries of F_1 Plants of the Cross *M. alba* × *M. dentata* and in Plants of the Parental Strains

Species or cross	No. of plants examined	No. of ovaries			Total no. of ovaries	Ave. no. ovules per ovary
		2-ovule	3-ovule	4-ovule		
M. alba	9	10	34	34	78	3.3
M. dentata	6	69	9		78	2.1
M. alba × *M. dentata* F_1	2	16	9	1	26	2.4

per ovary than the typical forms of the species but significant differences were noted among different plants of the strain. In one second generation inbred plant, 18 ovaries were examined and eight had two ovules, eight had three and two had four, whereas in another plant of the same line four ovaries had three, and 16 ovaries had four ovules. In the plants examined of the strain of *M. dentata* used as the pollen parent, ovaries with three ovules were found in addition to the two-ovuled ovaries typical of the species.

The ovule numbers recorded in the examination of parents and two of the three hybrids are summarized in Table I. With one exception, the ovaries of the hybrids bore either two or three ovules. The average number of ovules in the hybrids (2.4) falls between the averages for the parent lines but is closer to that of *M. dentata* than to that of *M. alba*. However, as already indicated, in the progeny derived from the self-pollination of the *M. alba* parent, considerable variation was noted from plant to plant so that the parent was probably heterozygous for the factor or factors governing this characteristic.

Fertility. Approximately 100 flowers on each of the three hybrid plants were self-pollinated by tripping the flowers with a toothpick tipped with fine emery cloth. No pods developed following this treatment. Microscopic examination showed that a large proportion of the pollen grains of each hybrid were clearly non-functional in that they were shrivelled and did not stain in a dilute IKI solution. A proportion of the pollen grains, 19.1 per cent in hybrid E256-1 and 12.7 per cent in E260-1, appeared to be normal, but no examination was made to determine whether the apparently normal grains germinated on the stigma and, if they germinated, whether the pollen tubes reached the ovary.

Chromosome Behavior and Fertility

Preliminary examination of chromosome behavior at meiosis was made by Dr. D. C. Cooper using smear preparations. No lagging chromosomes were found at the anaphase stages of the first division. Eight chromosomes were present on each of the equatorial plates of the second division, the process of meiosis apparently being normal.

When pollen of *M. alba* was applied to the flowers of the hybrids, pods were produced on only one hybrid, E260-1. A total of 191 flowers in 11 inflorescences on this plant received *M. alba* pollen and seven pods developed to maturity. The seven flowers producing pods occurred on inflorescences that were ready for pollination toward the middle of the flowering period rather than at random throughout this period (March 27 - May 20). In the succession of eighteen pollinated inflorescences, the fruitful racemes (Figure 5) were the 6th (one pod), the 7th (5 pods) and the 9th (one pod) with pollinations made on April 15, 21 and 26 respectively. This grouping of the productive ovaries indicates the probability that the egg cells participating in the formation of the seven seeds were not all carrying a complete complement of *M. alba* chromosomes but that some *M. dentata* chromosomes were also included. On the basis of a random distribution of the eight pairs of chromosomes, only one ovule in 256 would be expected to have an embryo sac with only *M. alba* chromosomes.

The seven seeds harvested from the one hybrid were planted. One seedling was weak and survived for only four days. Four seedlings were pale green although deeper in color than the F_1 hybrids and survived longer, but not beyond the seedling stage. The most vigorous one succumbed after 32 days when the first trifoliolate leaf was 5 mm. long. The remaining two plants have survived the seedling stage: on the one the foliage is normal green and at the time of writing fruits are developing from artificially self-pollinated flowers; on the other the foliage is light green and development is slightly slower than normal.

It may be possible, therefore, to transfer the coumarin-free character of *M. dentata* to *M. alba* but the two plants surviving from the first trials may constitute too small a sample to demonstrate this. It is expected that improvements in the grafting procedure will provide additional hybrids for further work. Some recent experiments suggest that within the species *M. officinalis* different plants are not all equally satisfactory as stocks. If this suggestion is confirmed, vegetative propagation of compatible stock plants should provide an adequate supply.

Summary

When *Melilotus alba* and *M. dentata*

are crossed, the F_1 hybrids are chlorophyll-deficient and live for only a few days. Such defective hybrids were grafted on normal plants and reared to maturity. Seven seeds and two mature plants have resulted from back crossing 191 flowers of the F_1 hybrid with *M. alba* pollen.

The F_1 hybrids resemble plants of *M. alba* in the shape of the stipule but tend to be intermediate between the parent species in flower color and number of ovules per ovary. Less than twenty per cent of the pollen grains appeared to be functional.

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Family Size in China

WRITING in the *American Journal of Sociology* (March, 1943), Francis Lang-Kwang Hsu presents a most interesting picture of the forces which mould the Chinese family. Recent field studies which show that the Chinese family averages about five individuals, had led to the erronous view that "such arguments as advanced by Lin Yu-t'ang regarding the virtues and evils of the large family are popular dramatization without any foundation in fact."

The traditional large Chinese family with several generations living under one roof, does exist, though only among the relatively very small wealthy class. Even here adverse economic conditions tend to break up these large aggregations, and there are also important disruptive psychological factors:

> The dual between the two basic relationships in the Chinese joint family is thus: A greater play of the husband-wife relationship tends to pull it asunder, while a greater play of the father-son relationship tends to result in the impressive but rare picture of many generations under one roof. Because rare, these families are usually objects of public admiration and royal awards on account of their being the highest development of the emphasis on the father-son relationship. They show, also, that large families of the dramatized type are not mere accidental curios, having nothing to do with the sociology of the Chinese family. They have a genuine foundation in the social organization.

The rarely achieved ideal of these large family groups, which are only realized under economic conditions far more favorable than most Chinese families are blessed with, undoubtedly does have a symbolic significance. "With and in the existing economic technology and structure, over-population provides the suitable background for a people the vast majority of whom are peasants of small means. Given this fact, it is little wonder that the predominant picture which this 'land of the large families' presents to investigtors is a small joint family of above five. But against this background, families grow large or small according to the adjustment between the two main relationships within each of them." The multi-generation family under one roof remains a fundamental ideal of the Chinese people.—R. C.

CHARACTERISTICS AND PRODUCTION OF OLD-TYPE NAVAJO SHEEP

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A DESCRIPTION of the characteristics and production of old-type Navajo sheep is of interest from two standpoints. In the first place, it will furnish western sheepmen with a "yardstick" to measure the advances they have made in their industry during the past six or seven decades. Also, it provides the foundation for a study in adaptation to environmental conditions. According to Salmon,[9] several million sheep were exported from the territory of New Mexico during the period from 1870 to 1880. Most of these sheep were sent to the surrounding states where they formed the basis for the early western range industry. These sheep were in all respects the same type as those owned by the Navajos who were furnished with native New Mexican sheep after their return from Bosque Redondo in 1868. A continued grading-up process has caused this early foundation stock to disappear from western ranges. A description of this native sheep will permit at least a partial evaluation of this process of improvement.

The primitive characteristics exhibited by the old-type Navajo sheep are of interest from the evolutionary standpoint. Unless records of these characteristics are secured at the present time, they may soon be lost for these sheep are now being raised in only a few isolated regions of the Navajo reservation and each year the number of this type is decreasing. Even at the Southwestern Range and Sheep Breeding Laboratory where a flock of old-type Navajo sheep is being maintained, the characteristics are being changed as a result of the breeding program. Through controlled matings and selection, production is being increased and many undesirable characters are being eliminated.

In the following presentation the term Navajo refers specifically to the old-type Navajo sheep. The descriptions given are of those characteristics to be found in the flock of Navajo sheep now being maintained at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico. The data presented are based upon the laboratory records of this flock for the years 1937 to 1942 inclusive.

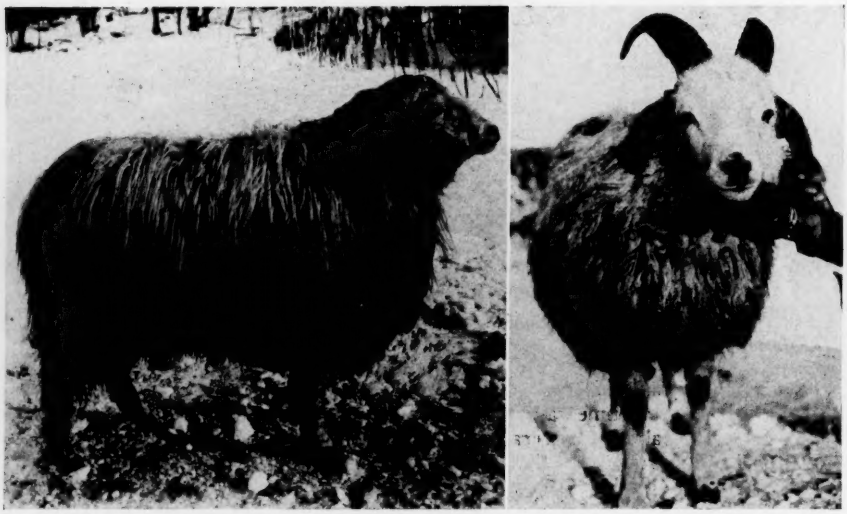
Characteristics of Navajo Sheep

The characteristics of Navajo sheep will be considered under three divisions: body, fleece, and physiological factors. Since the factors of Indian management which affect the type, size, and production of these sheep have been given in a previous publication[1] they will only be mentioned briefly in the present paper; the reader is referred to the former paper[1] for detailed discussion.

Body

During the last 400 years Navajo sheep have become well adapted to the region in which they live. They are able to subsist and produce a relatively greater amount of clean wool and lamb than are sheep of improved breeds that are introduced into this region and handled in a similar way. Their hardiness has resulted, in part at least, from both the Indians' management practices and the adverse feed conditions with which the animals have had to contend throughout their lives. A continuation of these adverse conditions over several centuries has allowed natural selection to play an

*This paper presents data collected during the conduct of the Bankhead-Jones project for the improvement of Navajo sheep, carried on in cooperation with the Bureau of Indian Affairs at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico.



NAVAJO RAMS
Figure 6

At the left is a normal-horned and at the right is a four-horned Navajo ram. Usually the secondary horns are much smaller. The ram at the left shows heavier bone and better conformation than the ram on the right, but his fleece is not so desirable as it is too long and coarse.

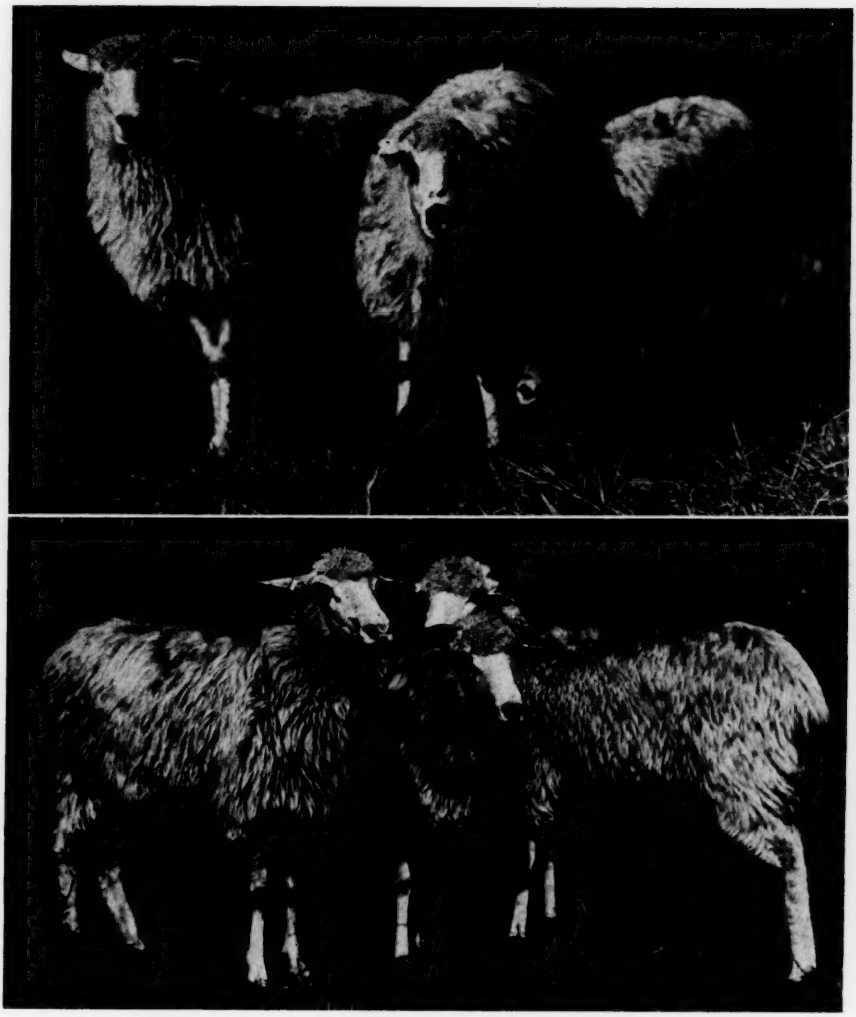
important role in the adaptation of the sheep to the region.

Navajo sheep lack the mutton conformation found in the improved breeds. They are long-legged, upstanding, narrow-bodied, and extremely light-boned. Their height and narrowness give them the appearance of being shallow-bodied, whereas in reality they possess a relatively deep body and have great depth of chest. The rump drops off abruptly instead of carrying out level to the tailhead. These sheep also lack the spring of forerib and width of chest which is desired in the mutton breeds. The ratio of width of chest to depth of chest was 0.58 for 85 yearling rams, and 0.61 for 296 yearling ewes. Hultz[5] found this ratio to be 0.88 for 25 Hampshire rams, and 1.00 for 25 Hampshire ewes. Width and depth of chest are usually regarded as indicative of constitution and vigor, yet despite their deficiencies in these characters Navajo sheep are very hardy.

Although they equal other range sheep in height, Navajo sheep weigh less. Mean weights of yearling and mature Navajo sheep are given in Table I. This table shows that the rams were not only heavier than the ewes as yearlings, but also that they made greater gains. Part of this disparity in size was accounted for by differences in management.

Following common range practice, the ewes remained on the range throughout the year. Except for a small amount of cottonseed cake, which was fed during the severest part of the winter, the ewes depended upon the range forage for sustenance. On the other hand, from the time the rams were weaned they were kept in a pasture and were given hay when the feed in the pasture was gone. Thus the rams were maintained on a higher plane of nutrition than the ewes, especially during the fall and winter. It was possible to handle the rams in this way only because the number of animals was small.

The weights in Table I, as well as a detailed growth study which is being carried on, show that by the time the



NAVAJO EWES
Figure 7

Above are three hornless Navajo ewes while below are three horned ewes. All these ewes show the "leginess" characteristic of Navajo sheep. They also show the lack of wool on the belly, another fairly common trait in these sheep.

ewes were bred at 19 months of age they had almost reached their mature weight. This fact indicates that Navajo sheep mature at a relatively early age.

Since no selection toward a fixed type had been practiced by the Indians, a varied miscellany of characters of relatively little economic importance is found in Navajo sheep. These include color and color patterns, wattles, short ears,

and horns. The badger face and reversed badger face patterns described by Roberts and White[11] for Welsh Mountain sheep are encountered. Spots on the ears, face, around the eyes, and on the nose and muzzle are frequently seen. Color on the feet and legs often accompanies the face spotting. This color varies from a light tan through a deep chocolate-brown to black. Occasionally piebald animals are also seen. These may be either black and white, brown and white, or black and tan. White on the poll and a white tipped tail are often encountered in self-colored animals. In Figure 8 several of the patterns found in these sheep are shown.

Wattles similar to those found on goats are sometimes present on Navajo sheep. Although the mode of inheritance has not been definitely worked out, the presence of wattles seems to to be governed by a single dominant gene. At docking time the wattles can be easily discerned for they are then about the size of a garden pea. By the time the sheep are yearlings the wattles have increased in size (Figure 8) until they are almost an inch in length and half an inch in diameter. They are quite vascular and when sheared off, as they usually are at the first shearing, bleed profusely.

The short eared condition is also encountered in Navajo sheep. Since the only matings which have been made were between normal-eared rams and short-eared ewes, it is not possible to state definitely whether the present character is the same as that described by Wriedt[13] and Ritzman[10] for other breeds of sheep. They found that the progeny of normal-eared rams × short-eared ewes showed a 1 :1 segregation for normal-ears and short-ears. The results obtained at our laboratory also gave a 1 :1 ratio for this type of mating.

The horned condition of Navajo sheep exhibits a wider range of forms than is found in any of the improved breeds. Detailed genetic analyses have not been completed, but at present it seems that more than one set of alleles is involved. This is in line with the findings of Ibsen and Cox.[6] Five distinct types of the horned condition are recognized. They are as follows: polled, scurs, small horns, normal horns, and multiple horns. The scurred and small horned conditions have been further divided into three classes: both attached, both loose, and one loose and one attached. The difference between the scurred and the small horned condition is usually quite marked, although an occasional individual is encountered on which classification is doubtful. At weaning time the small horns are usually from five to seven inches long, and about a half inch in diameter at the base. They vary from the above dimensions down to the size of large scurs. Many of the ewes exhibit horns which are similar in appearance to the Rambouillet-Dorset hybrids pictured by Warwick and Dunkle.[12] Most of the multiple horns occur in the rams, although an occasional ewe is found with three or four horns. The multiple horned condition is apparently caused by the splitting of the normal horn buds. Very often two of the horns are of normal size while the secondary horns are but little larger than scurs. If the two pairs of horns are of equal size, one pair will curve backward over the head, like goat horns, while the other pair curves to the side and downward. Such an animal is pictured in Figure 6. In the laboratory flock, sheep with three, four and five horns have occurred. Gregg[3] reported instances of rams having six horns.

Fleece

The Navajo sheep are characteristically open faced, clean legged, and often have little or no covering of wool on the belly. The open faced character is desirable in sheep that must maintain themselves on the range throughout the year, but bare bellies are one of the important factors contributing to light fleeces.

The fleeces produced by the Navajo sheep are classed commercially as carpet wool. In common with other carpet wools these fleeces are not so dense as finer, more uniform wools. Several types of fibers are likewise found in

GENETIC DEVIATIONS
Figure 8

The two upper photographs show extremes in spotting. The lamb at the left is predominantly black. Animals showing this variation may all be black except for a white tail tip and a white star on the top of the head. At the right is a lamb with black muzzle and black spots on the ears and around the eyes, the rest of the body being white. The pibald lamb shown in the lower left is predominantly white with considerable black spotting. At the right is shown a yearling ewe with wattles,—that on the right side of the neck having been partially sheared off.

them. Many fleeces exhibit as much luster as those from the long wooled breeds, while the shrinkage and grease content are lower than for most improved wools.

Navajos are sometimes called "hairy sheep" because of the long, coarse outercoat of fleece. Those sheep which show little or no mixing with the improved breeds possess a fleece made up of distinct outer and under coats. The outercoat is composed of long, coarse, hair-

like fibers, often attaining a length of ten to twelve inches in a year's growth, while the undercoat is made up of fine wool fibers rarely exceeding five inches in length. Figure 10 shows the range in quantity of outercoat usually encountered in Navajo wool.

As might be expected in a fleece of the type possessed by the Navajo, a great range in fiber diameter is found. In a cross section of a lock of wool the fiber diameters will often cover the range extending from about 10 to over 100 microns. This great range in diameters is due to the several types of fibers which make up the fleece. The undercoat is composed principally of very fine fibers ranging from 10 to 35 microns in diameter. In addition to the fine wool fibers, kemp fibers are found in the undercoat. The kemp fibers, shown in Figure 9, are slightly over an inch in length and usually have an average diameter in excess of 65 microns. The long, coarse outercoat is made up of non-medullated and medullated fibers. The medullated fibers may have either a continuous or discontinuous medulla. These coarse hair-like outercoat fibers are rarely finer than 35 microns, and few of them exceed 70 microns in diameter.

Graphs of frequency distributions of the diameters of Navajo wool fibers are usually characterized by marked skewness with a long tail on the coarse end. Often 90 per cent of the fibers are finer than the midpoint of the total range. The per cent of non-medullated, medullated, and kemp fibers occurring in successive five-micron class intervals shows that practically all the fibers between 10 and 35 microns are non-medullated. The medullated fibers are present in the central part of the range and are lost abruptly at about 65 microns. The percent of kemp fibers increases as the percent of non-medullated and medullated fibers decreases.

In the preceding classification and in the table that follows, the fibers were classified from cross sections made adjacent to the proximal end. It is recognized that this procedure may wrongly classify some fibers, particularly those with a discontinuous medulla or those showing other character differences along their length. A few such fibers do occur in Navajo wool, and are known as heterotypes.

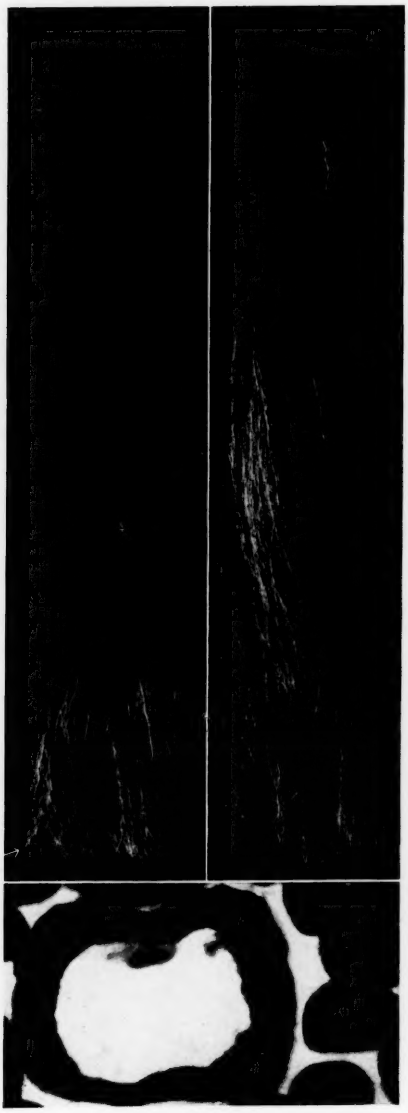
In Table IV the percent distribution of fibers finer and coarser than 40 microns is given according to fiber type. Laboratory analyses have shown that if the grade remains constant, the number and percent of fibers over 40 microns in diameter greatly affect the quality of the wool for hand spinning and weaving. The data in Table II show that kemp and medullated fibers play an important role in determining the suitability of the wool for these hand processes. It should be pointed out, however, that the distribution of the fibers over 40 microns is likewise of great importance. Other things being equal, the narrower the range covered by the coarse fibers the better adapted the wool is for handicraft uses.

The crimp in the outercoat fibers is neither so pronounced nor so regular as it is in improved wools. In the undercoat the crimp is more pronounced than it is in the outercoat, but not so regular nor so distinct as in improved three-eighth or quarter-blood wools. The percent of total length taken up by crimp is less in Navajo wool than it is for improved wools of quarter-blood fineness.

Variation is probably the most outstanding characteristic of the Navajo fleece. Great diversity in fiber type, in diameter, and length is found within the fleece of individual animals as well as between animals. The extreme amount of variation renders difficult the statistical analysis of fleece measurements. Differences between mean diameters up to five microns or three U. S. standard grades are often meaningless from a statistical standpoint.

Physiological Characteristics

The breeding program is not conducted with the view of obtaining exhaustive data on certain of the physiological characters of these sheep. The entire project is planned and conducted toward the production of a definite type of animal which is better suited to the needs of the



KEMP CONTENT
Figure 9

The kemp fibers are the short very thick fibers encountered in varying quantities in the wool of Navajo sheep. A section of a microphotograph is shown below with one huge hollow kemp fiber sectioned at the left and surrounded by a few of the other fibers to show comparative diameters. The kemp can be seen as large white fibers toward the base of the sample. Two of them intersect at the point indicated by the white arrow in the left hand figure. This sample has an excessive amount of kemp, while that at the right is much more desirable.

people; therefore information on estrus and allied subjects is gathered as a secondary product of the breeding work.

Information on the length of the estrus cycle was accumlated from the ewes which returned for service at breeding. All ewes were hand mated, thus it was possible to determine the date of breeding and, if the ewe again came into heat, the length of the estrus cycle. The average length of the cycle for the Navajo ewes was 16.44 ± .10 days. This is not unlike the figure given by McKenzie and Terrill[7] of 16.72 days for several breeds of improved sheep. Seventy per cent of the cycles were of either 16 or 17 days' duration and 94.7 per cent were within the range of 14 to 18 days. Five cycles of 29, 32, and 33 days' duration may have been double cycles, for some difficulty was encountered when a band of approximately 800 ewes was being sorted by teaser rams. Ewes showing a low intensity of heat were probably not bred because they failed to stand for the teaser ram.

Morrison[8] states that the average length of the gestation period is from 145 to 147 days for the mutton breeds, and about 152 days for the Merino and Rambouillet breeds. The average length of 2,130 pregnancies covering the six-year period 1937 to 1942 gave an average gestation period of 149.4 days. Only those ewes which were of straight Navajo breeding and which carried their lambs to term were considered in the above figure.

The fecundity of Navajo ewes is relatively high. The 2,722 ewes which lambed from 1937 to 1942 inclusive, produced 3,500 lambs or 128.6 lambs per 100 ewes lambing. Only 64 of these lambs were born dead. The percentage lamb crop was not so high as that of mutton breeds under farm conditions, but it was slightly higher than that of range Rambouillets. The remarkable feature was the low percentage of lambs born dead.

The average of 1.8 per cent dead is more remarkable when it is realized that slightly more than 16 per cent of the ewes were lambing for their first time.

A high rate of twinning in ewes is a characteristic sought after by most sheepmen. Indeed, the hothouse and shed lamb producer depends upon a high proportion of twins as an essential profit making factor. Regions where early spring lambs are produced also depend upon a large number of twins to offset the high feed and pasture charges. On the Navajo reservation, however, feed and weather conditions make a high rate of twinning undesirable.

From 1937 to 1942, 18 per cent of the Navajo ewes produced twins. In the breeding program no attempt is being made to increase the twinning tendency. It is believed that because of feed conditions, if each ewe produces one lamb and raises it successfully, a greater monetary return will be realized than if twins are produced. One large, well developed lamb, when sold as a feeder, will usually bring a higher price than two small ones, for the commercial buyer discriminates against the small stunted lambs.

Henning[4] has recently summarized the data on the secondary sex ratio in sheep. The average percent of sales, based on 127,587 sheep, was 48.96 per cent. The secondary sex ratio of Navajo sheep closely approximates that given by Henning. For the six years, 1937 to 1942, the percent of males, based on 3,521 lambs, was 48.51.

As explained by Henning,[4] the tertiary or adult sex ratio is practically unattainable in domestic animals. The reason for this is that many of the males are killed or otherwise disposed of before they reach maturity. The closest approach to a tertiary sex ratio for Navajo sheep is attained from the weaning records. These records show for the six-year period an average of 47.63 per cent males at weaning time. The difference, 0.88 per cent, between the secondary and tertiary ratio was probaboly brought about by the killing of a number of male twins.

During the six years, 1937 to 1942, 762 sets of twins were available for analysis as to the proportion of homo- and heterosexual twins. There were 185 sets of male-male twins, 373 male-female, and 204 female-female sets of twins. These figures show a close approximation to the 1 :2 :1 ratio which is expected by chance in the production of twins. The slightly greater, though statistically insignificant, proportion of female-female twins is likewise found in the data of Chapman and Lush[2] and Henning.[4] As these workers have pointed out for other breeds of sheep, if identical twins are produced in Navajo sheep they are very rare.

Production of Navajo Sheep

Under the system of management followed at the laboratory every attempt is made to handle the sheep with a minimum amount of disturbance to the animals and damage to the range. For this reason the production of both wool and lambs of the laboratory flock exceeds the production of similar sheep on the reservation under Navajo management. It is believed that the laboratory production records are, therefore, a truer index of the inherent capabilities of these sheep than any records which might be secured from flocks managed by Indians.

Lambs

The production record of the laboratory flock for the years 1937 to 1942, inclusive, is given in Table II. Differences between the records of individual years were encountered, especially in the weaning weights of the lambs. The differences in weaning weights were directly related to the amount of moisture received during the year. By way of illustration, in 1939 precipitation for the year totaled 10.09 inches, or 4.36 inches less than normal (14.45 inches). The lambs at weaning time averaged only 55.7 pounds. In 1941, however, the total moisture received was 18.47 inches, or 27.8 per cent above normal The average weaning weight of the lambs was 63.3 pounds for this year.

The table shows that 88.5 ewes lambed for every 100 ewes bred. Two rams of low fertility accounted for about four per cent of the number of ewes failing to lamb. Of the 1,839 ewes at the start of the breeding season, only 68 (3.7 per cent) failed to show evidence of estrum and thus were not bred. Death loss and other miscellaneous factors accounted for the remainder that failed to lamb.

Two factors intimately linked with and directly affecting the number of lambs raised to weaning age are the maternal instinct of the ewe and her ability to raise her lamb The maternal instinct has become highly developed in Navajo ewes. It is not uncommon for the older ewes to claim several lambs before giving birth to their own. Young ewes, especially of the fine wool type, will often fail to claim their first lamb; young Navajo ewes rarely, if ever, fail to claim theirs.

Coupled with, and of equal importance to, the maternal instinct is the ability of the ewe to raise her lamb. This ability depends largely on the milk she is able to produce. These ewes, considering the available food, are among the highest milk producers of any sheep. Their udders are large and well developed, with teats small enough for the young lamb to grasp easily.

The maternal instinct and the milk production of the ewe, as well as the hardiness of the lamb, were reflected in the high rate of lamb survival. For every 100 ewes bred, 111.2 live lambs were born and 89.8 per cent of these lambs were weaned.

The average weaning weight for all lambs, at an age of 139 days, was 57.0 pounds. As shown in the table these lambs weighed 7.8 pounds at birth, and made gains at an average daily rate of 0.35 pound. Their weight at birth was somewhat less than for most range sheep. Considering size at birth and range feed conditions, the weaning weight and pounds of lamb produced per ewe bred were satisfactory

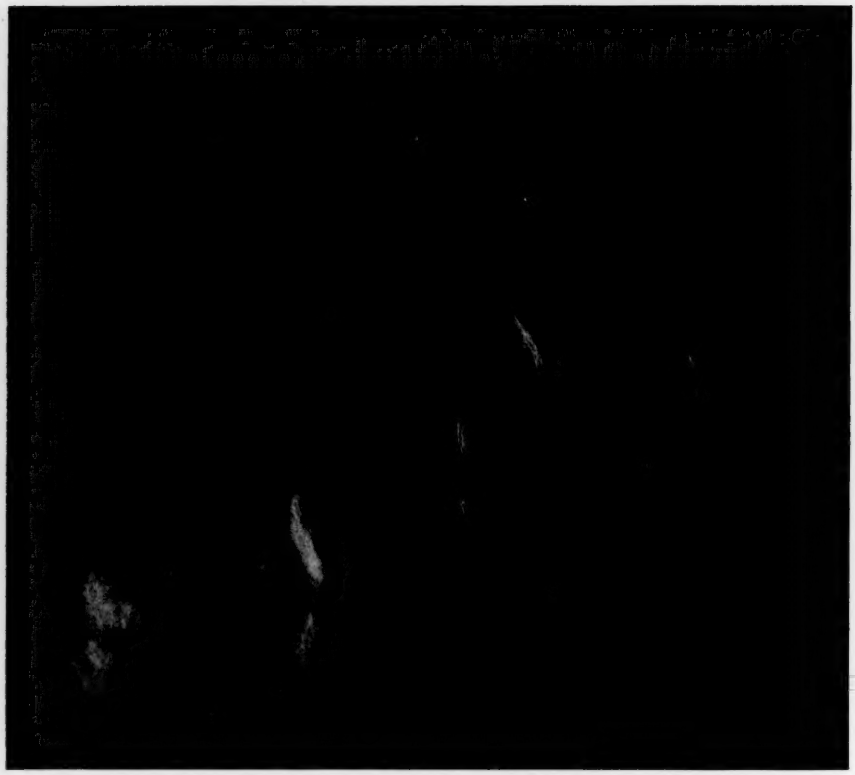
Blunn[1] has shown that because of feed and climatic conditions the Navajo Indians can produce only feeder lambs. Therefore, since feeder lamb buyers usually discriminate against the "hairy" Navajo lambs, and pay less per pound for them, the performance of these lambs in the feedlot is of utmost importance. The laboratory has conducted two feeding trials to determine the ability of Navajo lambs to gain in the feedlot. The results, while by no means conclusive, are indicative of the performance of these lambs.

While receiving a ration consisting mainly of alfalfa hay and corn they made an average daily gain of 0.29 pound for the two trials. Although these gains were not exceptionally high, they nevertheless show that the Navajo lambs can make economical gains. The average daily gains made by the Navajo lambs were only slightly smaller than the average of 0.31 pound given by Morrison[8] for 43 trials including 2,300 lambs on similar feeds. The dressing per cent and carcass grade reflected the poor mutton conformation of the Navajo lambs. The average dressing per cent was slightly less than 48. The average carcass grade was Good to Medium, with a range from Common to Choice. The lack of mutton type conformation was plainly evident in the dressed carcasses. They were long and angular, with prominent withers. The lack of spring of fore rib caused the carcasses to be extremely narrow back of the shoulder. There were also large amounts of internal fat, while the external finish was thin and spotty. The loin and ribs were usually well covered, while the hind legs were bare with patches of fat at the tailhead. The leg of mutton also lacked the desired plumpness and fullness.

The feeding trials demonstrated that Navajo lambs can make excellent gains in the feedlot, but the ultimate carcasses are not so desirable as are those of the improved breeds of sheep. Until the conformation of Navajo sheep is changed, the "hairy" lamb will continue to be sold at a discount.

Wool

Navajo sheep produce less wool per head than the eight-pound average for



VARIATION IN WOOL QUALITY

Figure 10

These samples show the usual range of outercoat in Navajo wool. The lock on the left is the most desirable, while that on the right is too long and too coarse for rug-making. The wool of the Navajo sheep is classified commercially as carpet wool, a much coarser type than that used for making clothing and for other purposes where fine spinning yarns are necessary.

all sheep in the United States.[14] In the laboratory flock, however, fleece weights have been increased through selection, controlled breeding, and proper range management.

The wool production of the original sheep in 1937 and the breeding flock of 1942 is given in Table III. From this table it is seen that fleece weights, especially those of the ewes, have increased considerably during the last six years. In 1942 the mature ewes produced 43.0 per cent and the yearlings 33.7 per cent more wool than the original ewes. The number of rams is too small to yield conclusive evidence of changes in fleece weight. The increase was 18.8 per cent for the mature and 0.8 per cent for the yearling rams.

The primary reason for this sex difference has been the rigid culling practiced in the selection of the rams for breeding use. The sheep might be bred to produce heavy fleeces, but the wool would be of limited value for Navajo handicraft use unless it possessed the desired physical characteristics and was of the right quality. Consequently the rams have been selected for breeding use almost solely on the basis of fleece type and quality

and little attention has been paid to density and fleece weight.

The lustrous, long, open type of fleece produced by Navajo sheep is usually light shrinking; therefore, the per cent yield of clean wool is high. The fleeces contain little grease, and most of the shrinkage is occasioned by the accumulation of sand and vegetable material in the wool. The difference of 4.5 per cent between the average shrinkage for the fleeces of the 1937 mature ewes and the 1942 yearling ewes was probably due to environmental causes. It has been found that in this semi-arid country variations between years caused differences of over 10 per cent in the shrinkage of wool produced by the same sheep in consecutive years.

Shrinkage percentages and production of clean wool were calculated in terms of commercial shrinkage based on clean wool containing 12 per cent moisture. On this basis in 1942 the mature ewes produced 33.4 per cent and the yearling ewes 24.6 per cent more clean wool than the 1937 ewes, despite the higher shrinkage in 1942. The corresponding data for the rams are not so clear cut; the 1942 yearling rams produced 4.1 per cent less clean wool than the 1937 rams while the 1942 mature rams produced only 19.7 per cent more clean wool than the original rams.

TABLE I. Comparison of yearling and mature sheep weights, 1937-1942.

Year	Ewes				Rams			
	Yearling		Mature		Yearling		Mature	
	Animals weighed	Average weight*	Animals weighed	Average weight*	Animals weighed	Average weight*	Animals weighed	Average weight*
	number	pounds	number	pounds	number	pounds	number	pounds
1937	99	91.7	532	96.5	29	138.0	7	159.0
1938	206	96.5	413	97.3	13	145.9	11	152.4
1939	208	89.7	390	97.6	27	145.9	24	170.2
1940	132	91.4	491	96.9	23	143.0	18	177.2
1941	70	102.9	241	103.3	4	152.0	31	175.7
1942	39	96.1	192	100.1	11	145.2	3	164.3
Total or average	754	93.7	2169	98.0	107	142.3	94	170.3

*Weighed prior to breeding in December.

TABLE II. Lamb production of Navajo ewes in the laboratory flock, 1937-42.

Ewes at beginning of breeding, number	1,839
Ewes lambing, number	1,628
Ewes lambing per 100 ewes bred, number	88.5
Lambs born, number	2,081
Lambs born per 100 ewes bred, number	113.2
Live lambs born, number	2,045
Live lambs born per 100 ewes bred, number	111.2
Lambs weaned, number	1,837
Lambs weaned per 100 ewes bred, number	99.9
Total weaning weight of lambs, pounds	104,779
Average weaning weight of lambs, pounds	57.0
Average birth weight of lambs, pounds	7.8
Average age of lambs, days	139.1
Average daily gain of lambs, pounds	0.35
Total corrected weaning weight to 140 days, pounds	105,364
Average corrected weaning weight, pounds	57.4
Lamb produced per ewe bred, based on corrected weaning weight, pounds	57.3

TABLE III. Wool production of Navajo Sheep, 1937 and 1942.

Year	Age and sex	Sheep	Average Fleece Weight		Average Shrinkage*
			Grease	Clean*	
		number	pounds	pounds	percent
1937	Mature ewes	747	4.19	2.81	33.0
	Mature rams	12	7.71	5.07	34.3
1942	Mature ewes	200	5.99	3.75	37.4
	Mature rams	3	9.16	6.07	33.7
	Yearling ewes	49	5.60	3.50	37.5
	Yearling rams	11	7.77	4.86	37.4

*Based on commercial shrinkages of clean wool containing 12 percent moisture.

Summary

New Mexico provided much of the stock used in founding the sheep industry of the West. A flock of Navajo sheep, similar to the original New Mexican sheep, is now maintained at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico.

Navajo sheep are hardy and well adapted to the range and climatic conditions found in the Southwest. In addition, they possess characters of body and fleece that differ widely from those possessed by present-day improved sheep of the region. Some of these characters, including color patterns, wattles, short ears, and the wide range of the horned

TABLE IV. Classification and fineness distribution of fibers found in Navajo wool.

Class	All fibers		Fibers under 40 μ in diameter		Fibers over 40 μ in diameter		Distribution of fibers	
							Under 40 μ	Over 40 μ
	number	percent	number	percent	number	percent	percent	percent
Total	25,013	—	20,417	—	4,596	—	81.63	18.37
Non-medullated	22,294	89.13	20,176	98.82	2,118	46.08	90.50	9.50
Medullated	2,301	9.20	237	1.16	2,064	44.91	10.30	89.70
Kemp	418	1.67	4	0.02	414	9.01	0.96	99.04

condition, are rarely if ever found among domestic sheep on western ranges.

The data which have been presented were taken from the flock records for the years 1937 to 1942, inclusive. Records on some of the minor characters were derived as secondary information from data used to further the breeding program.

Data on maturity, conformation, wool quality, and physiological characteristics are presented, and are compared with those for improved breeds of sheep. In such qualities as maternal instinct and milk production the Navajo sheep have reacted favorably to the long period of selection in an adverse environment.

The quality of carcasses and wool is discussed in relation to the economics of sheep production by the Navajos.

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A Matter of Genetiquette

To the Editor:

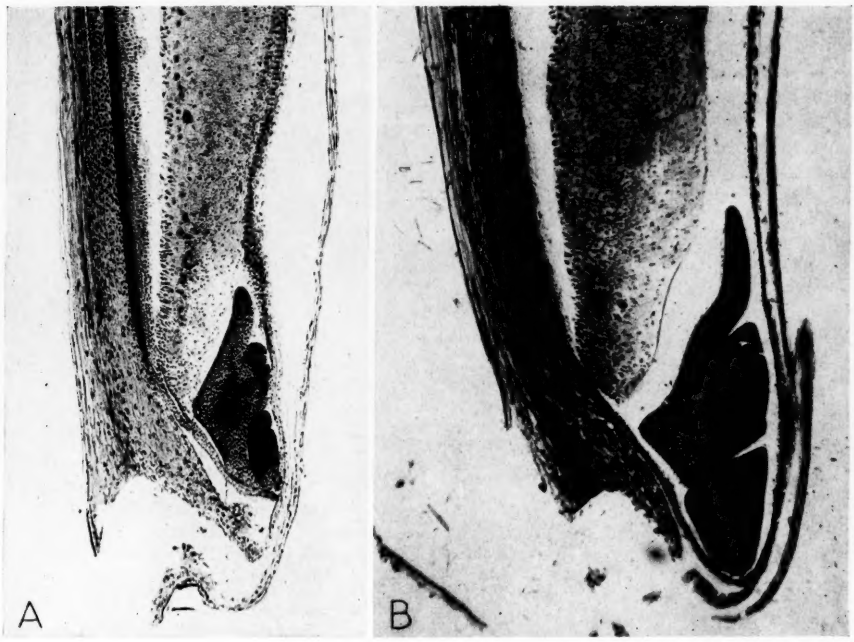
For the purpose of uniformity and clarity it would seem desirable to adopt regularity in the system of designating crossbreds. Crosses of animal breeds are customarily named with the breed of the sire first and the breed of the dam second. For example, a Landrace × Duroc-Jersey cross would indicate a Landrace boar mated with Duroc-Jersey sows. This method of nomenclature was not followed in a recent article in this Journal (Vol. 33, No. 12) which recorded the results of mating Holstein and Guernsey bulls with Ayrshire cows. To avoid confusion it seems desirable to bring up this matter for such consideration as seems warranted. In support of the convention of naming the sire's breed first it should be pointed out that pedigrees are usually prepared giving the sire first. Perhaps the female is coming into more prominence, and the ancient order should give place to something new. Should not uniformity and agreement be reached on this point, at least in animals?

George Haines

The Editor, a firm believer in the ancient aphorism "Any Post in a social storm," is all in favor of following the rules of proper procedure. As far as he has been able to discover, no formal stand with regard to this matter has ever been taken by any competent breeding-etiquette body but the unofficial convention appears to be as above stated. We thank Dr. Haines for bringing this matter to our attention.—Ed.

CLEAVAGE POLYEMBRYONY IN BARLEY

MERRITT N. POPE*



TWIN BARLEY EMBRYOS
Figure 11

Sagittal sections of the germ ends of barley seeds 10 days (*A*) and 12 days (*B*) after pollination showing twin embryos. × 40.

TWINNING occurs occasionally and in varying degrees in the cereals. Doubling of developing organs may occur and result in two complete seeds or, at the other extreme, in two embryos within the same embryo sac. Many gradations have been found between these two extremes. Theoretically, it should be possible for the meristem to produce two flower buds by separation of cells after an early division. When the separation is delayed the floral organs below may be single and those above double; for example, the twins may have a single lemma and a double palet, a single palet enclosing a double caryopsis or a single caryopsis with a double embryo. If cleavage of the egg cell should occur before fertilization, one-half might unite with a male nucleus and produce a normal diploid embryo and the other half could be stimulated to grow without fertilization and thus develop into a haploid. When cleavage occurs subsequent to fertilization, the two embryos are identical in chromosomal constitution and constitute what is known as cleavage polyembryony.

In 1940 a study was under way at Arlington Experiment Farm, Arlington,

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Va., in which culms of Manchuria barley were cut from the plant at flowering, placed in distilled water, and pollinated. This treatment seemed to have no adverse effect on the development of the embryo up to twelve days after pollination. However, cases of polyembryony occurred in two of the culms. It seems improbable that the polyembryony was a result of the treatment since never before has it been observed in seeds from culms similarly treated. The seeds from one culm were killed and fixed at ten days, and the other culm at twelve days after pollination.

Saggital sections of these two seeds were stained in Heidenhain's iron-alum haematoxylin and are shown in Figure 11. In each case the two embryos lie at an angle to each other and are separate and distinct. The embryos are unequal in size and the smaller ones might not have been able to survive in the competition of later growth. Both show differentiating tissues that are recognizable. Also division figures are present and examination of favorably lying cells indicated in all four embryos a chromosome count of 14 which is the diploid number in barley. Evidently both specimens are cases of cleavage polyembryony.

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Cultural Patterning of Family Size

The regional and urban concentration of the foreign born has important implications for the future composition of the American population. The various studies which have been made of the fertility of immigrant groups reveal a general pattern of high fertility of the first generation, with lower fertility for the second generation. Apparently, the immigrants from the high fertility agrarian areas of Europe have very rapidly acquired the values of the urban, industrial civilization into which they have come. The extent of transformation in the fertility patterns of successive generations of immigrants is revealed by the net reproduction rates for the various states and areas in 1940. The regions with the highest proportions of foreign born were New England, the Middle Atlantic, the East North Central, and the Pacific. These were also the only major regions with net reproduction rates below unity. Within these regions, net reproduction rates were lowest in the urban areas, and here the immigrants were concentrated. The Southern regions of relatively high fertility had negligible proportions of immigrants. The only states with net reproduction rates above unity and a proportion of foreign born above the national average were Maine and the Northwestern states of Michigan, Wisconsin, Minnesota, North Dakota and Montana. The assimilation of the immigrants and their descendants to the reproductive patterns of the urbanized, industrialized culture into which they have come is so nearly complete that the nationality succession of the future will not be that of immigrants succeeding natives but natives of the great agricultural areas of relatively high fertility succeeding the descendants of the immigrants. — *Population Index*, July, 1942.

RICE DWARF MUTATIONS AND THEIR INHERITANCE*

N. E. JODON AND H. M. BEACHELL†

ALL dwarfs in rice reported in the literature are described as thickset, with all parts of the plant shortened, the leaves stiff, and broad in proportion to length, the panicles compact, and the seeds small and rounded. However, the various dwarfs differ somewhat in plant height. This article describes four types of dwarfness in rice, only two of which cause a shortening of all plant parts. Data on the inheritance of three dwarf varieties also are presented.

Kadam[5] made crosses among 11 dwarf varieties of rice and described five different dwarf types, four of which were represented by single varieties.

Reviews on rice genetics[4,6,8] indicate that dwarfness in rice usually is due to a single factor difference with dwarfness recessive in normal × dwarf crosses, as reported by several workers, including Jones.[9] Sugimoto[3] reported a dominant dwarf that, except for size, resembled the pure-line in which it originated. Akemine[1] was the first to cross two dwarf varieties. The F_1 was normal and in the F_2 a ratio was observed of 9 normal : 3 dwarfs of the larger type : 3 dwarfs of the smaller type : 1 dwarf plant of a new very small type.

Nakayama[7] found that in panicles of one normal and of three dwarf varieties the cell division and size was equal up to the 37th day after seeding. Soon after this period, branching and growth began in the largest dwarf, while cell division remained inactive in the two smaller dwarfs. No differences in cell size were noted.

Dwarf Rice Varieties in the Southern States

Among the thousands of rice varieties introduced by the United States Department of Agriculture were two dwarfs, C. I. 5403-2 from Guatemala and Daikokune from Japan. Daikokune is shorter than C. I. 5403-2. A cross between these two varieties was made by J. W. Jones of the Bureau of Plant Industry, and only dwarf plants were obtained in F_1 and later generations. In F_2 there was some segregation for plant height, but only within the range of the parents. (Unpublished data.)

Eight dwarf mutations in rice were collected in the Southern States between 1936 and 1941. These consisted of four distinct types. The identity of these dwarfs with those described by Kadam[5] has not been determined. Three of the types were found as recessive mutations in the field and the fourth represents a double recessive isolated from a cross between two dwarf types. The number of genotypes among the four types described below has not yet been fully established.

Description of Dwarf Types

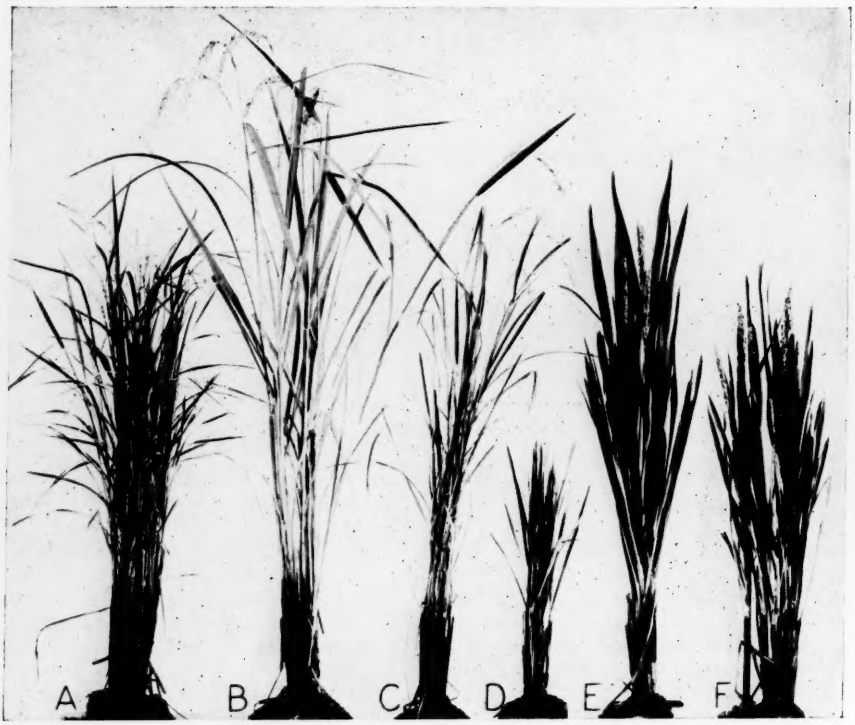
Thickset Dwarf. The plants of this type are about one-third as tall as normals, have short, thick stiff leaves, extremely compact panicles, and small rounded grains. The dwarf varieties C. I. 5403-2 and Daikokune have these characteristics. The dwarf growth habits in this type are apparent in the seedling stage.

A thickset dwarf, found in the variety Blue Rose near Bay City, Texas, was received from F. A. Rakestraw in 1936. This dwarf resembles Blue Rose in pubescence, lack of anthocyanin color, straw hull color, susceptibility to Cercospora leaf spot, and time of maturity.

A plant identical in appearance with

*Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Louisiana and Texas Agricultural Experiment Stations.

†Assistant Agronomists.



PARENTAL AND REPRESENTATIVE F_2 PLANT TYPES FROM THE CROSS GRASSY DWARF × THICKEST BLUE ROSE DWARF

Figure 12

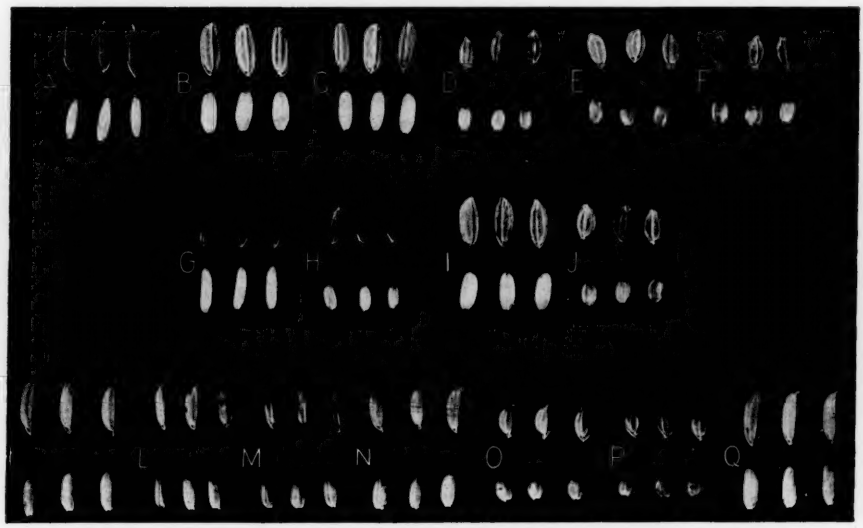
A—Grassy Dwarf parent, *B*—normal, *C*—Grassy Dwarf, *D*—Double Dwarf (double recessive), *E*—Thickset Dwarf, *F*—Thickset Blue Rose Dwarf parent.

the thickset dwarf from Blue Rose was received from C. Roy Adair, Rice Branch Experiment Station, Stuttgart, Ark., in 1941. This dwarf had been found by Earnest Pufahl in Blue Rose rice near Cherry Valley, Arkansas.

Another thickset dwarf was found in Rexoro at the Rice Experiment Station, Crowley, La., by J. J. Webster in 1939. This dwarf resembles Rexoro in lack of pubescence, faint purple color of the apiculus, gold hull color, resistance to Cercospora leaf spot, and time of maturity, and is similar to the Blue Rose dwarf in height.

Intermediate Dwarf. The plants of this type are intermediate in height between normal and thickset dwarf, or about two-thirds as tall as normal plants. Of the two dwarfs collected, one was found in a field of Blue Rose near Nome, Texas, by J. W. Jones in 1939. The plants of this dwarf have leaves of normal size but the internodes of the culm are shorter than normal, thus reducing the height. The panicles are shorter and more compact, and the spikelets are shorter and rounder than those of Blue Rose. In other aspects, the variety is the same as Blue Rose.

An F_3 row of the cross C. I. 1239 × Early Prolific, at Crowley, La., segregated for an intermediate dwarf type in 1941. The height of this dwarf also was intermediate between the thickset dwarf type and normal. The leaves ap-



SEED AND KERNEL TYPES OF NORMAL AND DWARF VARIETIES

Figure 13

A—Grassy Dwarf parent, *B*—Normal, *C*—Grassy Dwarf, *D*—Double Dwarf, *E*—Thickset Dwarf, *F*—Thickset Blue Rose Dwarf parent, *G*—Rexoro, *H*—Thickset Rexoro Dwarf, *I*—Blue Rose, *J*—Thickset Blue Rose Dwarf, *K*—Normal Storm Proof × Spain Jap selection, *L*—Grassy Dwarf, Beaumont, *M*—Intermediate Blue Rose Dwarf, *N*—Intermediate Dwarf (F_3) Crowley, *O*—Thickset Dwarf C. I. 5403-2, *P*—Thickset Dwarf Diakokune, *Q*—Normal F_3 of C. I. 1239 × Early Prolific.

peared less thickened and the spikelets were larger than in the thickset dwarf. There were 13 plants in the row of which seven were normal and six dwarf. The dwarf plants were not uniform in size.

Grassy Dwarf. The grassy dwarf type is characterized by a profusion of slender tillers many of which fail to produce panicles and seed. The number of spikelets on the fertile and partially fertile panicles is greatly reduced, but the seeds produced are of normal or nearly normal size. In the seedling stage the growth of grassy dwarfs appears to be equal to that of normal seedlings. The grassy dwarfs could not be distinguished at the time of submergence of the field two weeks after seedling emergence. The term "grassy dwarf" is applied because of the general appearance of the plant is suggestive of a tuft of some bunch grass.

Two mutations of this type were found, each in segregating populations, one in 1937 at the Rice Experimental Station, Crowley, La., and the other in 1938 at Texas Agricultural Substation No. 4, Beaumont.

Double Dwarf. This type originated from a cross between the thickset dwarf and grassy dwarf types. It is smaller than the thickset dwarf type, probably has greater tendency to sterility, and like the grassy dwarf type tends to have numerous tillers.

Inheritance of Grassy and Thickset Dwarfs

Origin and Inheritance of Crowley Grassy Dwarf

The grassy dwarf found at the Rice Experiment Station, Crowley, La., appeared as a recessive class in an F_2 population of the cross Carolina Gold × C. I. 4966. The cross was made in 1936, and both parents and the F_1 plants were of normal height. Three of the

four F_2 progenies, grown in 1937, gave dwarfs in numbers in close agreement with a 3 : 1 ratio. The growth habit of the dwarfs was unmistakable, but they showed segregation for other characters. Since the parent plants and all the F_1 plants were of normal height and since the fourth family when grown later did not segregate it seems probable that one of the parents was heterozygous for dwarfness and that three instead of two of the F_1 progenies segregated for dwarfness. Thus a mutation must have occurred in the heterozygous parent variety previous to 1936.

All three F_2 families and an F_3 generation, as well as a natural cross with one of the families, segregated in close agreement with a 3 : 1 ratio for normals and grassy dwarfs. The total plant segregations were 1,003 normal and 351 grassy dwarfs. This gave a P value of 0.50-0.30 for a 3 : 1 ratio. The close fit to a 3 : 1 ratio precludes the possibility that the dwarf might have originated as the result of complementary factor interaction. Further crosses were made between other lines of the parent varieties, but no dwarfs appeared in F_2. Unfortunately, the identical parent lines of Carolina Gold and C. I. 4966 used in the original cross were not maintained so that it is not known which was heterozygous for dwarfness.

Origin and Inheritance of Beaumont Grassy Dwarf

The grassy dwarf found at Texas Agricultural Substation No. 4, Beaumont, appeared in 1938 in an F_3 line of the cross (Storm Proof × Spain Jap. F_5 selection) × Supreme Blue Rose. In a single row there were 20 normal and seven grassy dwarf plants. In 1939 the dwarfs and six normal lines bred true, and 14 normal lines segregated, giving 278 normal and 83 dwarf plants. These numbers are in good agreement with a 3 : 1 ratio, $P = 0.50\text{-}0.30$. Five of the F_3 plants grown in 1939 were transferred to a greenhouse and seed was obtained for growing in 1940. These five segregating lines gave 918 normal and 342 dwarf plants. These numbers agree reasonably well with an expected 3 : 1 ratio, $P = 0.10\text{-}0.05$. The totals for 1939-1940 were 1,196 normal to 425 dwarf plants, which agrees well with a 3 : 1 ratio, $P = 0.30\text{-}0.20$.

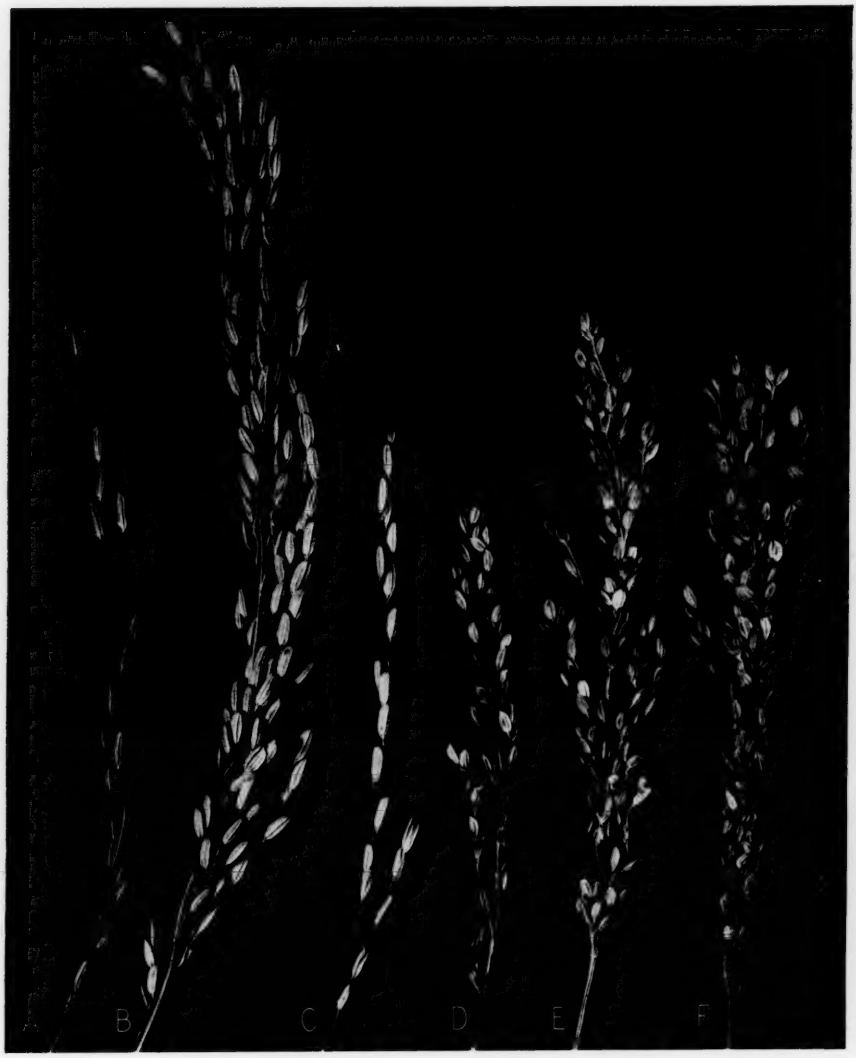
Thickset Dwarf × Normal

Crosses between the Thickset Blue Rose Dwarf and Normal Blue Rose were obtained in 1938 by pollinating unemasculated dwarf florets after natural blooming. Previous attempts to make the cross on emasculated dwarf florets were unsuccessful.

Two F_2 progenies were grown in 1940 and two in 1941. In both years only two classes, normal and thickest dwarf plants were distinguishable. Each of the four progenies showed a deficiency of dwarfs, on the basis of a 3 : 1 ratio, $P < .01$. The total plant segregations were 856 normal to 131 dwarf. This also gave a P value of $< .01$ for a 3 : 1 ratio. The deficiency in the dwarf class probably was due to the slow seedling elongation and root growth of the dwarf plants while the soil was drying out. Conditions for germination and emergence were very unfavorable in the field in both 1940 and 1941. Five heterozygous F_3 lines were grown in 1941 under conditions more favorable for emergence and of a total of about 162 (unspaced) plants obtained 32 were thickset dwarfs. These numbers are in satisfactory agreement with the expected 3 : 1 ratio ($P = 0.20\text{-}0.10$), but the dwarf class was again deficient. Eight F_3 dwarf lines grown in 1941 showed no variation from the original dwarf.

To obtain additional information on segregation in this cross the remnants of two families were germinated on absorbent cotton in the laboratory. The thickset dwarfs were easily recognizable in the first or second leaf stages by the shortness and broadness of the leaf blade and the general stocky appearance. They appeared to be of a darker green color due, perhaps, to thicker tissues. The segregation obtained in the laboratory, 101 normal and 39 thickset dwarf plants, agreed very well with the expected 3 : 1 ratio ($P = 0.90\text{-}0.80$).

The height of the normal and thickset



PARENTAL AND REPRESENTATIVE F_2 PANICLE TYPES FROM THE CROSS GRASSY DWARF × THICKSET BLUE ROSE DWARF

Figure 14

Left to right: *A*—Grassy Dwarf parent, *B*—normal, *C*—Grassy Dwarf, *D*—Double Dwarf, *E*—Thickset Dwarf, *F*—Thickset Blue Rose Dwarf parent.

dwarf plants in an F_2 population was measured 26 days after sowing. Measurements were taken from the seed to the tip of the second leaf. The modal height of the thickset dwarf plants centered at 10-12 cm. as compared with 20-22 cm. for the normal segregates. The heights of the thickset dwarf plants, however, ranged from eight to 18 cm. while those of the normals ranged from eight to 26 cm. Thus, overlapping in height at this stage was sufficient to preclude accurate classification of the two types on the basis of height alone.

Grassy Dwarf × Thickset Dwarf

Crosses of Crowley Grassy Dwarf × the Thickset Blue Rose Dwarf were obtained in 1939. The grassy dwarf was emasculated by the hot water method of Jodon[2] and used as the female parent. The F_1 plants were normal in appearance. Four F_2 families were grown in 1941 and the segregation is shown in Table I. In addition to normal and the parental dwarf types, a new smaller dwarf type appeared. This form is designated "Double Dwarf" and no doubt represents the double recessive class.

Plant, panicle, grain, and kernel types of the parental dwarf varieties and representative F_2 segregates of this cross are shown in Figures 12 and 14 and grain and kernel types of other dwarfs in Figure 13.

The thickset and the double dwarf classes were greatly deficient as shown in Table I. These populations were grown under the same unfavorable conditions for seedling emergence as mentioned previously, and a poor fit for the expected 9 : 3 : 3 : 1 ratio resulted. The data indicate, however, that the grassy dwarfs are at no great disadvantage in the seedling stage.

TABLE I. Segregation in the F_2 for Normal and Dwarf Types in the Cross Grassy Dwarf × Thickset Blue Rose Dwarf

F_1 Plant number	Normal	Thickset Dwarf	Grassy Dwarf	Double Dwarf	Total
33-1	21	7	5	0	33
33-2	43	7	5	0	55
33-3	33	7	10	2	52
*	172	37	50	11	270
Total	269	58	70	13	410†

*F_1 of another family grown in greenhouse at Arlington Experiment Farm, Rosslyn, Va.
†$X^2 = 17.855$; $P = 0.01$.

Summary

Four types of dwarf mutations in rice, Thickset Dwarf, Intermediate Dwarf, Grassy Dwarf, and Double Dwarf, were collected in the Southern rice area between 1936 and 1941.

In crosses with normal types, both Thickset Dwarf and Grassy Dwarf behaved as simple recessives. When the Grassy Dwarf type was crossed with the Thickset Dwarf, the F_1 plants were of normal height. The F_2 generation showed a 9 : 3 : 3 : 1 ratio of normal, grassy dwarf, thickset dwarf, and double dwarf plants, respectively. The Double Dwarf type appeared as a double recessive class.

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